AD-A050 588 ARINC RESEARCH CORP ANNAPOLIS MD F/G 16/4.2
LCC/DTC TASKS CONDUCTED FOR MX WEAPON SYSTEM PROGRAM.(U)
JAN 78 H N BUCHANAN, R R NELSON, J N SCHAEFER F04606-76-A-0087
UNCLASSIFIED 1953-03-2-1692 NL

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Publication 1953-03-2-1692

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Summary Report

LCC/DTC TASKS CONDUCTED FOR MX WEAPON SYSTEM PROGRAM

January 1978

Prepared for

SPACE AND MISSILE SYSTEMS ORGANIZATION
Norton Air Force Base, California

Under Contract F04606-76-A-0087-R901

ARINC RESEARCH CORPORATION

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 1953- 03-2-1692

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER: Summary rept.

4. TITLE *(and Subtitle)*: LCC/DTC TASKS CONDUCTED FOR MX WEAPON SYSTEM PROGRAM.

5. TYPE OF REPORT & PERIOD COVERED: Oct 76 - Jan 78

6. PERFORMING ORG. REPORT NUMBER: 1953-03-2-1692

7. AUTHOR(s): H. N. Buchanan, D. E. Sweet, R.R. Nelson, J. N. Schaefer

8. CONTRACT OR GRANT NUMBER(s): F04606-76-A-0087-R901

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
ARINC Research Corp.
2551 Riva Road
Annapolis, Maryland 21401

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS:
SPACE AND MISSILE SYSTEMS ORGANIZATION
Norton Air Force Base, California

12. REPORT DATE: Jan 1978

13. NUMBER OF PAGES: 15 (12) 16 p.

14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*:
SPACE AND MISSILE SYSTEMS ORGANIZATION
Norton Air Force Base, California

15. SECURITY CLASS. *(of this report)*: Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*:
Unclassified / Unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

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DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

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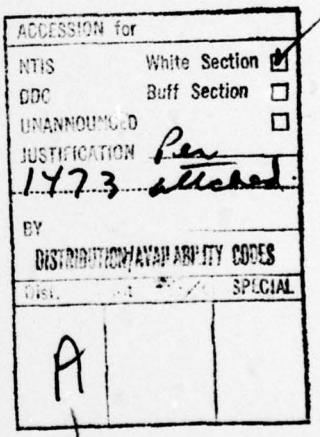

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1 INTRODUCTION

1.1 SCOPE

Under Contract F04606-76-A-0087-R901 with the Space and Missile Systems Organization (SAMSO), Norton Air Force Base, CA, ARINC Research Corporation has conducted tasks in support of the MX Weapon System Program. The period of performance on this contract was October 1976 through January 1978. The work performed included tasks in the areas of both life cycle cost/design-to-cost (LCC/DTC) and integrated logistic support (ILS). This report summarizes the Corporation's activities in the area of LCC/DTC. Services provided in the ILS categories are the subject of a separate summary report.

1.2 BACKGROUND

1.2.1 MX Program

The MX Program has been implemented to provide the technology base for the development of an improved land-based strategic missile weapon system. Efforts are being directed toward the design, development, and deployment of an ICBM system within one of two nuclear-hardened, multiple-aim-point (MAP) basing alternatives. The two currently favored basing options are the buried trench and shelter.

At the time work was initiated under this contract, the program was in the System Validation Phase and the DSARC II milestone was imminent. Initial efforts were directed toward developing LCC/DTC inputs to work statements to be utilized in contracting for the Full Scale Development (FSD) Phase. Subsequent program changes extended the System Validation Phase and inserted a System Definition (SD) Phase to be completed prior to DSARC II. ARINC Research Corporation's work was still oriented toward the FSD phase, with overlap to occur between the preceding Validation and System Definition phases and succeeding Production/Deployment Phase.

1.2.2 Contract Management

The LCC/DTC tasks of the contract were performed under the direction of the LCC/DTC Manager within the ICBM Program Office System Engineering Division

(SAMSO/MNNX). The Engineering Directorate forms an integral part of the ICBM Program Office and is designated MNN. The ILS tasks of the contract were managed separately by the Manager of the Logistic Planning and Analysis Division (MNLA), a division of the Directorate of Logistics (MNL).

1.2.3 Contract Requirements

The contract statement of work requirements applicable to this study are summarized and commented upon in the following paragraphs.

1.2.3.1 Life Cycle Cost/Design to Cost Methodology

> "The Contractor shall conduct an analysis to define and recommend the overall LCC/DTC methodology to be used in the conduct of the MX Program. The analysis shall include as a minimum the following:
>
> a. Review of the ICBM Program Office philosophy regarding the part to be played by LCC/DTC in the development and production of the MX Weapon System.
>
> b. Analysis of the LCC/DTC activities to be performed during the MX acquisition program, including the definition and scheduling of major LCC/DTC milestones.
>
> c. Analysis of how the MX cost goals will be established, at what points in the program the goals will be updated, and the basis for the formulation of each updated goal.
>
> d. Analysis of potential roles of LCC/DTC in contracting agreements. The analysis shall consider the significance of costing with respect to the various procurements by defining the cost incentives to be used; the source selection techniques related to costing; the cost estimate monitoring techniques to be applied to each contract, and various general contracting provisions to be included in each procurement.
>
> e. Analysis of the required ICBM Program Office management procedures to be established for conducting the LCC/DTC activities as a significant design tool.
>
> f. Analysis of the organizations, offices, and personnel responsible for the various LCC/DTC activities."

COMMENTS: This task had the objective of assisting the ICBM Program Office in 1) structuring and defining a sound, effective LCC/DTC program for MX Weapon System development and implementation, and 2) implementing the LCC/DTC program by developing a formal MX LCC/DTC Methodology Plan and structuring portions of major RFPs/SOWs to ensure contractor participation in and support of life cycle cost control/reduction.

The LCC/DTC Methodology Plan was to encompass the entire life cycle of the weapon system, with emphasis placed on cost control achievable during FSD. The RFP/SOW inputs prepared were originally directed toward the FSD procurements. As the program plans changed to include a System Definition Phase, the inputs were altered appropriately to account for SD and for the FSD options.

1.2.3.2 Develop Model

"The Contractor shall conduct an analysis to define and develop the MX MAP Weapon System LCC/DTC model. This analysis shall be performed in two parts, which are to define the model requirements and to develop cost algorithms.

"Define Model Requirements

"The analysis to be performed to define the model requirements shall include as a minimum the following:

a. Review MX system and program plans to identify the design parameters and those cost elements pertinent to the model.

b. Review currently existing data bases which are relevant to the MX Program.

c. Review and analyze the Operation and Support (O&S) cost concept definitions, provided by the ICBM Program Office, to identify their treatment in the LCC/DTC model.

d. Determine the system analysis options to be included in the model, based upon the identification of anticipated cost driving elements, system configuration options being considered, program plan options, and design/cost sensitivity relationships requiring analysis for the design selection process.

e. Review the model requirements analysis of the existing Air Force force effectiveness models to be used by the ICBM Program Office in evaluating the alternative system designs.

f. Define the necessary interfaces between the effectiveness models and the LCC model.

"Develop Cost Algorithms

"The analysis to be performed to define the cost algorithms shall include as a minimum the following:

a. The derivation of appropriate cost algorithms for each cost element and system/O&S option identified in the preceding subtask.

b. Review of existing cost models for applicable cost algorithms which could be used for various elements of the MX model. Where no suitable existing cost algorithms can be identified, new algorithms shall be derived."

COMMENTS: The objective of this task was to define and mathematically formulate a life cycle cost model to support weapon system design trades. The model was to be designed in modular form to allow updating as the various weapon system elements mature. The model algorithms and structure were to reflect LCC sensitivities to system and subsystem design parameters and to facilitate cost analysis of multiple design variations. Absolute cost estimates of a budgetary nature are generated by a separate cost model already available at the Program Office.

1.2.3.3 Develop Data Base

"The Contractor shall identify, coordinate and collect the data bases necessary to provide inputs to the MX MAP Weapon System LCC/DTC model. These data shall be those required to complete input data files for the model, rather than the data necessary to develop CERs or derive cost algorithms."

COMMENTS: Delivery of this data base, in a format compatible with the ultimate computer implementation of the model, was to provide the Program Office with a reference data set and allow proper execution of the model.

1.2.3.4 Implement Baseline Model

"The model defined in paragraph 3.2 of the SOW [1.2.3.2 above] shall be implemented in computer program form and installed on a computer available to the ICBM Program Office. The implementation language used shall be FORTRAN."

COMMENTS: The baseline model and data base, as originally defined, were to be an early version of the model provided to support FSD source selection activities. As the MX Program was rescheduled, the source selection process was delayed considerably, and the baseline model became a milestone for technical coordination.

1.2.3.5 Test and Document Baseline Model

"When the Baseline LCC model has been installed on the Air Force computer, it shall be fully checked out by executing test cases with known results."

1.2.3.6 Expand LCC Model

> "As the MX Program concept becomes better known and more refined, the Contractor shall update the LCC model to incorporate better cost algorithms, expand the level of detail available in the cost algorithms and sensitivity analyses, and eliminate model features no longer needed due to settlement of system design issues."

COMMENTS: The model was originally to be updated using information gained during FSD source selection, thus reflecting new design concepts, detail, and trade sensitivities. As the MX schedule changes extended the source selection beyond the end of the ARINC Research contract, the model expansion effort was dedicated to refinement and update of the baseline model, improving model flexibility, and expanding design interactions represented in the model.

Both the baseline and expanded versions of the model and data base were documented for Program Office use.

2
IMPLEMENTATION OF LCC/DTC WORK STATEMENT TASKS

A review of the latest ICBM Program Office, Strategic Air Command, and Air Force Logistics Command documentation and plans for the MX Weapon System formed the baseline of information for the LCC/DTC tasks. These documents included weapon system configuration concept descriptions, operating and support concepts, development schedules and procurement approaches, existing cost and effectiveness models, and selected subsystem descriptions. A series of information-gathering interviews was conducted with the subsystem Project Offices to gain insight into design and procurement considerations.

The LCC/DTC methodology was developed as the first deliverable item under the LCC/DTC tasking. However, careful consideration was given to the procurement concepts and FSD SOW tasks that would be required to implement the methodology. Thus, when the RFP/SOW inputs were prepared, they were fully coordinated with the LCC/DTC methodology.

The LCC/DTC model was developed as a tool for use within the ICBM Program Office and was implemented on a CDC computer available to that office. The model was designed to be easily updated as system and subsystem concepts changed, and to be compatible with other Program Office models such as those for effectiveness analysis and the existing Scheduled Program Allocation of Resources and Costs (SPARC) LCC model. During the development process, the LCC/DTC model was reviewed with the Program Office (AFSC), SAC, and AFLC to ensure proper treatment of design, operation, and support of the weapon system. Prior to final delivery, the model was reviewed with the Program Office through a series of meetings with the major Project Offices.

2.1 LCC/DTC METHODOLOGY

The LCC/DTC methodology for MX was prepared in close coordination with the MX LCC/DTC Manager within the Engineering Directorate. Following a review of existing MX Program documentation and plans, a series of interviews with Project Offices was arranged. In preparation for those meetings, a standard questionnaire

was developed to gather information related to the design, cost, risk, procurement environments, and subsystem development management concepts.

Based upon analyses of this information, Program Office management guidance, DoD policy regarding LCC/DTC, and previous experiences on a variety of military programs, an approach to cost control and reduction for the MX Weapon System was developed. Through numerous reviews and iterations of the approach at the Program Office, including a briefing presentation by ARINC Research to the MX Life Cycle Cost Working Group on 20 January 1977, the approach was refined into its final form and published as an approved Program Office document on 6 June 1977.

As documented, the MX LCC/DTC methodology implements control and reduction of weapon system life cycle cost by establishing DTC goals for subsystem first-unit production costs and learning rates, and goals for subsystem design parameters which most influence operating and support (O&S) costs. Control of weapon system costs and allocation of cost goals to subsystems is the responsibility of the ICBM Program Manager.

The MX LCC/DTC Plan delivered on 6 June 1977 documents the following aspects of the methodology:

a. Purpose
b. Scope
c. LCC/DTC program objectives
d. Approach to implementation
e. LCC/DTC management and tasks for program participants, including task responsibility assignments
f. Resource and task schedules
g. Glossary of terminology.

2.2 RFP/SOW INPUTS

Based upon the information gathered at the Program Office and in conformance with the MX LCC/DTC Plan, analyses were conducted to develop SOW inputs for the major SD/FSD RFPs. These inputs included a standard set of tasks in the LCC/DTC area, CDRL items and delivery schedules related to LCC/DTC reporting, and suggested procurement concepts for motivating associate contractors to pursue cost reductions. The LCC/DTC tasks and CDRL items were designed to be selected or

deleted as appropriate to tailor each procurement for the subsystem in question. The CDRL items and their delivery dates were related to major program and subsystem events and decision points so as to provide appropriate LCC/DTC information to support those events and decisions. Suggestions for procurement concepts were specifically tailored for each major procurement, based on DoD policy, Program Office policy as defined by the LCC/DTC Plan, the anticipated competition scenario, the design maturity and risk of the subsystem, and Project Office management concepts.

Table 2-1 lists the procurements for which RFP/SOW inputs and procurement concept suggestions were prepared. Submittal dates for draft and final submittals are also indicated.

TABLE 2-1. RFP/SOW INPUT SUBMITTALS

Procurement/Subsystem	Submittal Date	
	Draft	Final
Propulsion and Standardized SOW/CDRL	3 Jan 77	4 Mar 77 (CDRL) 20 Apr 77 (SOW)
Guidance and Control (3 separate procurements)	28 Jan 77	20 Apr 77
Assembly, Test, and System Support	7 Apr 77	4 May 77
Re-entry System	15 Apr 77	4 May 77
Software	15 Apr 77	4 May 77

2.3 MX MAP WEAPON SYSTEM LCC/DTC MODEL

Two versions of the MX MAP Weapon System LCC/DTC model were developed: one for the Buried Trench Weapon System and one for the Shelter Based Weapon System. Both are designed to support design trades by estimating weapon system life cycle cost changes resulting from design, operating, and support parameter changes.

The models treat all three major phases of the weapon system life cycle: R&D, acquisition, and operation and support. To the extent possible, model inputs are structured to reflect areas where trades still remain possible, and the cost algorithms

for all three life cycle phases are structured to reflect cost sensitivities to those inputs. While the models are largely dependent on input data changes to account for subsystem design interactions, certain explicit interactions are built into the model.

The cost estimating methodology used in the models is a mixture of cost estimating relationships (CERs), "bottoms-up" type engineering estimates, and cost throughputs. The R&D cost algorithms are generally throughput or CER types, with the latter attempting to relate both subsystem design and development program planning factors to development costs. Throughputs are used where few significant design trades are possible or where no historical data were available. The acquisition cost algorithms are generally CER or engineering estimate types, with some throughput items for completeness. The algorithms attempt to relate unit production costs to design parameters for which there is flexibility for trades. To the maximum extent possible and practical, design parameters were selected that impact both subsystem acquisition costs and weapon system O&S costs. The O&S cost algorithms provide a representation of the actual operation and support of the weapon system, based upon design and operating parameter inputs. O&S costs are calculated by expenditure category, with parameters from each weapon system element being input sequentially to a given algorithm, and costs for that expenditure type being accumulated over all weapon system elements.

The models were implemented in FORTRAN, as specified in the contract, which also called for installation of the models on a computer to be designated by the ICBM Program Office. A survey by the Program Office revealed that no computer with adequate capacity and the ability to execute classified runs was available within the Program Office. Therefore a computer operated by a nearby commercial firm was designated for final program implementation. That facility offered the ability to operate on classified data, and was already being utilized for other classified analysis in support of the MX Program.

An unclassified baseline version of the model was first implemented on an IBM time-share service convenient to ARINC Research. The model was then installed on the IBM computer designated by the Program Office. During the installation, two problems became apparent:

a. An unanticipated level of effort was expended structuring the model to fit the small computer, and

b. The compile and execution times on that computer were extremely long, which would have made the model's maintenance and use impractical from both the economic and turnaround-time standpoints.

A review of the above problems with the Program Office resulted in a decision to select a more suitable computer. A CDC computer was identified, offering sufficient capacity for the models, classified operation capability, increased operating speed, and ready availability to the Program Office. The contract was redirected to implement the models on that computer. This redirection necessitated a modification to the contract, extending the period of performance and adding funding to accomplish the program revisions necessitated by the change of computers.

Both versions of the model were subsequently installed on the CDC computer. User manuals for the models were provided, in a form suitable for incorporation into the Program Office's planned model configuration control mechanism. A data base with which to execute the program was delivered, together with the final version of the model.

3
DATA SUBMITTALS

For the LCC/DTC work under this contract, nine CDRL items were required. A brief description of each of these items follows.

a. Monthly Status Reports (CDRL 001A2)

Monthly status reports were provided to apprise SAMSO/MNNX of the progress being made, potential or actual problems, and plans for the work to be performed during the following month. (Delivered the 15th day of each month.)

b. Summary Report (CDRL 002A2)

This report summarizes the LCC/DTC work completed by ARINC Research during the performance period of the contract. (Delivered in draft form on 23 December 1977, and in final form on 31 January 1978.)

c. MX LCC/DTC Plan (CDRL 003A2)

This document defines the ICBM Program Office approach to LCC control and reduction for the MX Weapon System. It also delineates LCC/DTC tasks and responsible program participants. The plan was published as an official Program Office document. (Delivered in draft form on 18 January 1977, and in final form on 17 June 1977.)

d. MX LCC/DTC RFP/SOW Inputs (CDRL 004A2)

Standardized and tailored inputs were provided for Program Office consideration and incorporation into SD/FSD RFPs. The inputs included SOW task descriptions, CDRL item definitions and schedules, introductory and explanatory information related to LCC/DTC, suggestions regarding source selection criteria with respect to LCC/DTC, and suggestions for contractor incentive approaches. (Modular deliveries, as shown in Table 2-1, page 8.)

e. MX LCC/DTC Model Requirements (CDRL 005A2)

To coordinate model capabilities with the Program Office during model development, the requirements for model performance were documented and reviewed prior to model implementation. Requirements were documented for both the baseline and expanded models. (Baseline version delivered on 10 February 1977; expanded version delivered on 3 August 1977.)

f. MX LCC/DTC Model Cost Algorithms (CDRL 006A2)

As another step in coordinating model development, the mathematical cost formulations for each cost element were documented and reviewed prior to computer coding. Algorithms for both baseline and expanded models were documented. (Baseline version delivered on 21 June 1977; expanded version delivered on 21 October 1977.)

g. MX LCC/DTC Data Base (CDRL 007A2)

Complete input data files for the LCC/DTC model were delivered to the Program Office to allow initial execution of the model. Data values were documented to indicate their source. (Baseline delivered on 12 October 1977; expanded version delivered on 25 January 1978.)

h. MX LCC/DTC Model Documentation (CDRL 008A2)

Users manuals were provided for the LCC/DTC model to document model content and explain its use. The documents describe the purpose and overall structure of the model, define the cost algorithms for all cost elements, describe the computer implementation and use of the model, and present source program listings and sample results. (Baseline delivered on 12 October 1977; expanded version delivered on 25 January 1978.)

i. MX MAP Weapon System LCC/DTC Model (CDRL 001A3)

The computer program implementing the LCC/DTC model was delivered in the form of punched-card decks, as installed on the CDC computer. Separate decks were provided for the Buried Trench and Shelter Based systems. (Delivered on 21 December 1977 (BTWS) and 31 January 1978 (SBWS).)